Building Research Establishment Digest

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Roof drainage: part 2

Sizes of valley and parapet gutters, outlets or receivers, and rainwater pipes

For valley gutters, the *plan* area of the double roof should be taken as the effective area to be drained.

The sole of a valley or parapet gutter should be at least 300 mm wide; a convenient profile is obtained by sloping the sides to the same pitch as the roof, up to a height which gives sufficient flow capacity, and then turning a vertical upstand as the freeboard. The depth of the freeboard should be two-fifths of the gutter depth, up to a maximum of 75 mm (see Fig 4).

A gutter that cannot be allowed to overflow should be provided with two or more outlets; a weir overflow at the end of the gutter may also be needed.

Flow capacity for free discharge

Gutters should normally be provided with outlets designed to accept the flow from the gutter without increasing the depth of flow in the gutter ('free discharge') except where the minimum practicable gutter size provides a large surplus capacity (see page 3).

The depth of flow in a straight level gutter discharging freely decreases from the maximum at the far end (the high end) to the outlet. It may be assumed that the depth of flow at the outlet (H_0 in Fig 4) is half the depth at the far end. When the gutter is flowing at its maximum capacity, therefore, the depth at the outlet is half the gutter depth excluding freeboard (D). A fall in the gutter will increase the rate of flow but no figure can be quoted for this; it should be regarded as an increase in the safety margin against overflow.

In a gutter discharging freely, the flow capacity (Q) is approximately

$$\sqrt{\frac{A^3}{B}} \times 10^{-4} \text{ litres/second}$$

where A = area of flow at outlet (mm²) and

B = width of water surface at outlet (mm)

The chart in Fig 5 shows the plan area of roof to be drained for values of B and A. Thus for any rectangular or trapezoidal gutter section and any depth of flow, values of B and A can be calculated or measured from drawings of gutter sections and the equivalent roof area can be obtained; alternatively, the depth of flow at the gutter outlet (required in calculating the size of rainwater pipe) can be determined for a given roof by trial and error.

The charts, Figs 5–7, are based on a rate of rainfall of 75 mm/h. For any other rate of rainfall, the measured plan area must be multiplied by $r/75$ (where r is the design rate of rainfall in mm/h) to obtain the appropriate gutter or rainwater pipe size from the charts. Conversely, the plan area of roof that can be drained by a given gutter obtained from the charts must be multiplied by $75/r$.

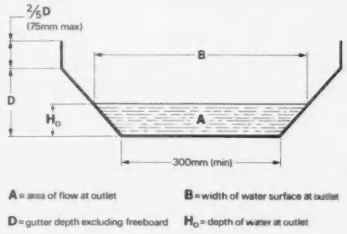

Fig 4 Dimensions at gutter outlet

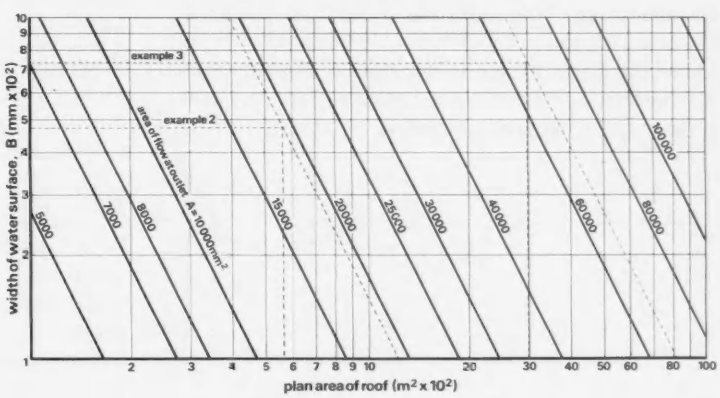

Fig 5 Relationship of roof area and flow dimensions

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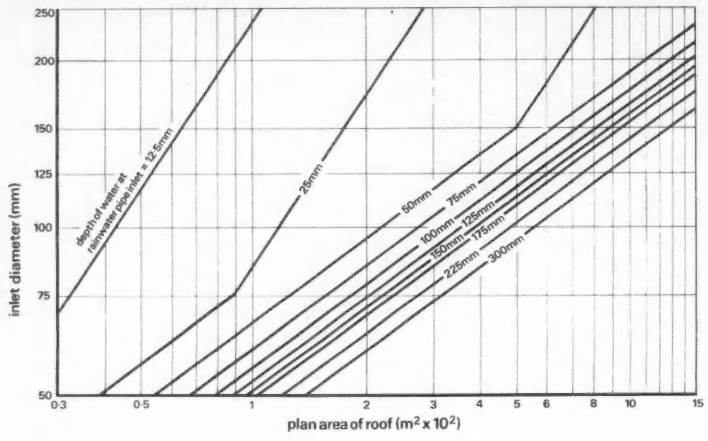

Fig 6 Roof area to be served by rainwater pipe inlet (no swirl)

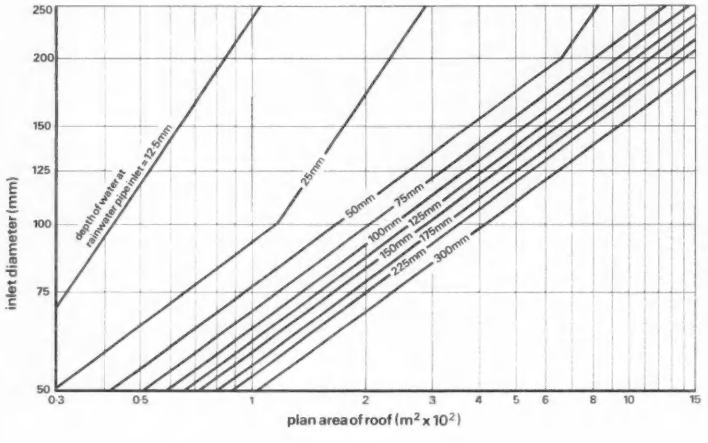

Fig 7 Roof area to be served by rainwater pipe inlet (with swirl)

Box-type receiver

Wherever possible, gutters should discharge into a box-type receiver, the depth of which can be chosen so as to permit the use of a rainwater pipe of convenient size.

The receiver should be at least as wide as the maximum gutter width and it should be long enough to prevent the flow from the gutter over-shooting the box. The top of the box should be level with the top of the gutter except where the box is external to the building, when the outer edge is kept lower to provide an emergency overflow. A suitable shape for an external box-type receiver is shown in Fig 8, in which the recommended depth of the edge is $H_d + 2/3H_d$, where H_d is the depth of water at the inlet to the rainwater pipe required to give the necessary discharge capacity (obtained from Figs 6 or 7 according to whether or not there is swirl, see below). The length L_b of the box should be $2\sqrt{F.H_O}$, where F is the fall between the water surfaces (not less than $H_O + 2/3H_d$).

Where a box is situated part way along a length of roof, a separate value for L_b should be calculated for each gutter length draining into it and the two lengths added to give the total length of the box.

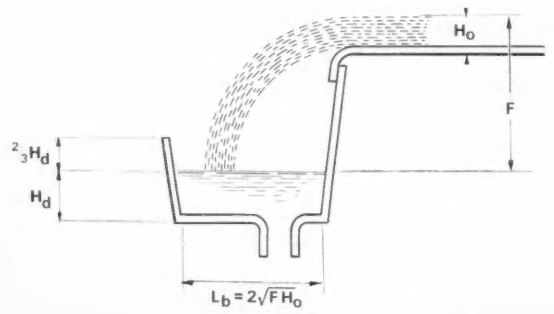

Fig 8 Dimensions of box-type receiver

Rainwater pipes

Where the gutter discharges directly into a rainwater pipe, the rainwater pipe inlet (or gutter outlet) should be designed to allow free discharge from the gutter. The discharge capacity of the rainwater pipe inlet depends on the diameter of the inlet, the depth of water (head) over the inlet and on whether the water swirls about the inlet.

The charts (Figs 6 and 7) give the roof area that can be drained by an inlet of given diameter, at various heads, for inlets with and without swirling, respectively.

Swirl can be neglected if the centre line of the inlet is at a distance less than its diameter from the nearest vertical side of the gutter or box. Swirl can also be suppressed by placing a vertical guide vane along the axis of the gutter, over the rainwater pipe inlet. In the absence of swirl, the inlet acts as a weir for values of the ratio H_i/D up to 1/3 and the discharge capacity of the inlet (Q_i) in litres/second is

$$\frac{D}{5000}\sqrt{H_i^3}$$

where D = diameter of inlet (mm) and

H_i = head of flow over the inlet (mm).

Where H_i/D is greater than 1/3, the inlet acts as an orifice and

$$Q_i = \frac{D^2}{15\,000}\sqrt{H_i}$$

Fig 6 has been prepared from the above expressions.*

Swirl will occur when the centre of the inlet is at a distance greater than its diameter from the nearest vertical side of the gutter or box (unless suppressed by a vane). The inlet then acts as a weir with the same discharge rate as in the absence of swirl for values of H_i/D up to 1/4; above this, the inlet acts as an orifice but swirling will reduce its discharge capacity to

$$\frac{D^2}{20\,000}\sqrt{H_i}.$$

The chart in Fig 7 is applicable to this situation.*

When sizing the inlet to a rainwater pipe leading directly from the gutter, the head H_d should be taken as the depth of flow at the gutter outlet (H_0 in Fig 4). If, however, the gutter discharges into a box-type receiver to which the rainwater pipe connects, the head is the depth of water in the box (H_d in Fig 8).

The diameter of the rainwater pipe can be reduced to two-thirds of the effective inlet diameter provided that the transition is gradual over a length of not less than the diameter of the inlet.

If the inlet is covered by a grating, the effective discharge capacity of the inlet must be calculated from the unobstructed area of the grating.

Gutters with large surplus capacity

The minimum practicable gutter size may be considerably greater than the hydraulic considerations demand. The excess capacity can then be utilised to reduce the required size of rainwater pipe by permitting the depth of flow in the gutter to rise above that for free discharge. This applies only where the rainwater pipe leads directly from the gutter.

The procedure involves some trial and error to discover the smallest size of rainwater pipe inlet that will not cause the gutter to overflow, and is as follows:

Select a convenient size of rainwater pipe inlet and, for the roof area to be drained, read the head H_d (ie the depth of water at the rainwater pipe inlet) from Figs 6 or 7, as appropriate.

From H_d, calculate the width of the water surface B at the gutter outlet, and the area of flow A.

Using these values of B and A, obtain from Fig 5 the equivalent plan area of roof for free discharge.

Calculate $R = \dfrac{\text{plan area of roof to be drained}}{\text{equivalent plan area for free discharge}}$

Using R, from Fig 9 read $X = \dfrac{\text{max. depth in gutter}}{\text{depth at gutter outlet}}$

Calculate $X \times H_d$. If this is greater than the gutter depth (excluding freeboard), the procedure must be repeated using a larger diameter rainwater pipe inlet. If, however, this depth is less than the gutter depth, a smaller inlet can be tried until the smallest which will not result in overflowing of the gutter is arrived at.

Example 2

The plan area of a roof to be drained by a valley gutter is 25 m × 20 m = 500 m²; the roof pitch on either side of the gutter is 30°. The gutter is to be trapezoidal in section, with sides sloping at 30° and a sole width of 300 mm. What depth of gutter and what size of rainwater pipe are required?

Gutter

The required depth is found by trial and error for assumed values of the depth, H_0, at the gutter outlet.

Try H_0 = 25 mm:

then, for the given gutter section,

$$B = 386 \text{ mm}; \qquad A = 8580 \text{ mm}^2$$

From Fig 5, the corresponding roof area is under 200 m² which is substantially less than the area to be drained.

Therefore, try H_0 = 75 mm:

then, B = 560 mm; A = 32 250 mm².

The corresponding roof area (from Fig 5) is over 1000 m², which is on the safe side, but uneconomical.

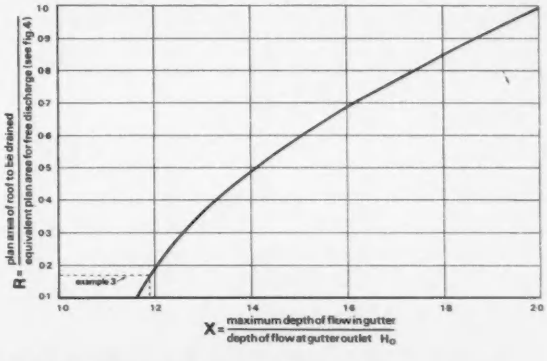

Fig 9 Relationship between depth of flow at outlet and maximum depth of flow for gutter with restricted outlet

* These formulae use rounded figures but are sufficiently accurate for use in calculations. The exact formulae, before rounding, were used in preparation of the charts, Figs 6 and 7.

Therefore, try $H_0 = 50$ mm:

then, $B = 473$ mm; $A = 19\,300$ mm^2

and, from Fig 5, the corresponding roof area is 560 m^2 (approx) which is the approximate plan area of the roof to be drained. (The roof area obtained from the assumed depth of flow will rarely equal exactly the area of roof for which the gutter is required but the exact depth of flow can be obtained by interpolation). For free discharge, the maximum depth of flow in the gutter is twice the depth at the outlet; therefore the required gutter depth is 2×50 mm $= 100$ mm. To this should be added a freeboard of 40 mm.

Rainwater pipe

Where the rainwater pipe is connected directly to the gutter, the depth of flow at the gutter outlet found above, ie $H_0 = 50$ mm, is used in calculating the diameter of the rainwater pipe inlet (gutter outlet).

As marked on Fig 7, with $H_0 = H_d = 50$ mm, and a plan area of 500 m^2, the required diameter of the rainwater pipe *inlet* is 180 mm. The *pipe* diameter can, however, be reduced to 120 mm; as explained on page 3, a reduction to not less than two-thirds of the inlet diameter is admissible.

If the gutter discharges into a box-type receiver, it may be possible to use a smaller rainwater pipe inlet by increasing the head over this inlet.

Try a 150 mm rainwater pipe inlet:

from Fig 7, the required head $H_d = 90$ mm, and the difference F between levels of the water surfaces in the gutter and the box should not be less than

$$H_0 + 2/3H_d$$

that is, $F \geqslant 50 + (2/3 \times 90)$ mm $= 110$ mm.

The length of the box should not be less than

$$2\sqrt{F.H_0} = 2\sqrt{(110 \times 50)} = 148{\cdot}3 \text{ mm}$$

and the bottom of the box should not be less than

$$(H_d + 2/3H_d) = 150 \text{ mm}$$

below the bottom of the gutter.

Try a 125 mm rainwater pipe inlet:

from Fig 7, the required head $H_d = 175$ mm.

$$F \geqslant 2/3H_d + H_0 = (2/3 \times 175) + 50 = 170 \text{ mm}$$

$$L_b \geqslant 2\sqrt{(F.H_0)} = 2\sqrt{(170 \times 50)} = 185 \text{ mm}$$

$$H_d + 2/3H_d = 175 + (2/3 \times 175) = 291 \text{ mm}$$

that is, the use of the smaller diameter inlet requires that the bottom of the box should be at least 291 mm below the bottom of the gutter.

Example 3

A gutter of the same shape as in Example 2 is 200 mm deep, excluding freeboard.

(i) *What is the maximum area of roof that can be drained to it?*

(ii) *If the gutter is to drain a roof 25 m × 20 m = 500 m^2, what is the smallest rainwater pipe into which it can discharge directly?*

(i) The maximum capacity of the gutter is obtained when it discharges freely. The depth at the outlet is then half the gutter depth, that is,

$$H_0 = \frac{200}{2} = 100 \text{ mm};$$

$$B = 646{\cdot}6 \text{ mm};$$

$$A = 47\,330 \text{ mm}^2.$$

From Fig 5 the maximum roof area which this gutter can drain is 2000 m^2.

(ii) If the roof area to be drained is only 500 m^2, the maximum depth of flow in the gutter for free discharge is only 100 mm (*see Example 2*). The excess capacity can be utilised by letting the head at the outlet exceed that for free discharge by reducing the diameter of the rainwater pipe inlet.

Try a 135 mm rainwater pipe inlet:

from Fig 7 the required $H_d = 125$ mm and therefore

$$B = 732 \text{ mm}; \quad A = 64\,500 \text{ mm}^2.$$

From Fig 5 the equivalent plan area of roof for free discharge is 3000 m^2.

Therefore,

$$R = \frac{500}{3000} = 0{\cdot}15$$

and using Fig 9 as indicated,

$$X = 1{\cdot}19$$

Therefore the maximum depth in the gutter

$$= 125 \times 1{\cdot}19 = 150 \text{ mm}$$

which is on the safe side. Therefore, try a 120 mm rainwater pipe inlet. From Fig 7 the required H_d is 225 mm, which is greater than the gutter depth. The minimum size of rainwater pipe inlet is therefore 135 mm.

The rainwater pipe diameter can then be reduced to two-thirds of its inlet diameter, ie to 90 mm, as already explained.

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